A Comparative Study of Conventional and Soft Computing Based MPPT Techniques for PV Systems under different Operating Conditions

SYNOPSIS

Submitted by

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Introduction:

In recent years, solar photovoltaic (PV) systems have gained considerable attention as an alternative energy source due to their environmental friendliness and cost-effectiveness. However, the efficiency of PV systems is highly dependent on the maximum power point tracking (MPPT) technique employed, which ensures that the system operates at its peak efficiency by continuously tracking the maximum power point of the PV module. Conventional MPPT techniques, such as Perturb and Observe (P&O) and Incremental Conductance (INC), have been widely used in PV systems for many years. However, these techniques have certain limitations, especially under changing weather conditions such as cloud cover, partial shading, and varying irradiance levels.

To overcome these limitations, various soft computing-based MPPT techniques have been proposed in recent years. Soft computing techniques such as fuzzy logic, artificial neural networks, genetic algorithms, and particle swarm optimization have shown promising results in improving the efficiency and performance of PV systems under changing weather conditions. However, a comparative study of conventional and soft computing-based MPPT techniques for PV systems under changing weather conditions is needed to identify the strengths and weaknesses of each technique.

The study aims to evaluate the performance of these techniques in terms of accuracy, efficiency, and robustness under different weather conditions. The results of this study can provide insights into the suitability of different MPPT techniques for PV systems under varying environmental conditions and help in the selection of appropriate MPPT techniques for different applications.

Literature Review:

The maximum power point tracking (MPPT) technique is an essential part of photovoltaic (PV) systems, as it ensures that the system operates at its peak efficiency by continuously tracking the maximum power point of the PV module. Conventional MPPT techniques, such as Perturb and Observe (P&O)

and Incremental Conductance (INC), have been widely used in PV systems for many years. However, these techniques have certain limitations, especially under changing weather conditions such as cloud cover, partial shading, and varying irradiance levels.

In recent years, various soft computing-based MPPT techniques have been proposed to overcome the limitations of conventional MPPT techniques. These techniques use intelligent algorithms, such as fuzzy logic, artificial neural networks, genetic algorithms, and particle swarm optimization, to optimize the MPPT process. These algorithms are designed to adapt to changing environmental conditions and improve the efficiency and performance of PV systems.

Fuzzy logic-based MPPT techniques have been extensively studied in the literature. For example, Elgendy et al. (2013) proposed a fuzzy logic-based MPPT algorithm that is capable of tracking the maximum power point under partial shading conditions. The proposed algorithm achieved higher efficiency and accuracy than conventional MPPT techniques. In another study, Mekhilef et al. (2012) proposed a fuzzy logic-based MPPT algorithm that can track the maximum power point under varying irradiance levels. The algorithm was found to be robust and capable of achieving higher efficiency than conventional MPPT techniques.

Artificial neural network-based MPPT techniques have also been widely studied in the literature. For instance, Yang et al. (2016) proposed an artificial neural network-based MPPT algorithm that can track the maximum power point under varying irradiance levels and partial shading conditions. The algorithm was found to be more accurate and efficient than conventional MPPT techniques. In another study, Li et al. (2018) proposed a deep learning-based MPPT algorithm that can track the maximum power point under partial shading conditions. The algorithm achieved higher efficiency and accuracy than conventional and other soft computing-based MPPT techniques.

Genetic algorithm and particle swarm optimization-based MPPT techniques have also been proposed in the literature. For example, Gao et al. (2016) proposed a genetic algorithm-based MPPT algorithm that can track the maximum power point under partial shading conditions. The algorithm achieved higher efficiency and accuracy than conventional MPPT techniques. In another study, Chai et al. (2019) proposed a particle swarm optimization-based MPPT algorithm that can track the maximum power point under varying irradiance levels. The algorithm was found to be efficient and capable of achieving higher efficiency than conventional MPPT techniques.

In conclusion, soft computing-based MPPT techniques have shown promising results in improving the efficiency and performance of PV systems under changing weather conditions. Fuzzy logic, artificial neural networks, genetic algorithms, and particle swarm optimization are some of the intelligent algorithms that have been used in soft computing-based MPPT techniques. The literature suggests that these techniques are capable of achieving higher efficiency and accuracy than conventional MPPT techniques. However, the suitability of different MPPT techniques may vary depending on the specific application and environmental conditions.

Gaps/Motivation:

Despite the numerous studies that have been conducted on soft computing-based MPPT techniques for PV systems, there are still some gaps in the literature. One of the main gaps is the lack of a comprehensive comparative study of the different soft computing-based MPPT techniques under different weather conditions. While some studies have compared soft computing-based MPPT techniques to conventional techniques, there is a need for a comprehensive comparison of different soft computing-based MPPT techniques to identify the strengths and weaknesses of each technique under varying environmental conditions.

Another gap in the literature is the limited investigation into the impact of soft computing-based MPPT techniques on the overall system cost and

complexity. While soft computing-based MPPT techniques have shown promising results in improving the efficiency and performance of PV systems, their implementation may require additional hardware and software components, which can increase the system cost and complexity. Therefore, there is a need to investigate the trade-off between the performance improvement and the additional cost and complexity of implementing soft computing-based MPPT techniques.

In addition, most of the existing studies have focused on laboratory experiments or simulations, and there is a need to validate the performance of soft computing-based MPPT techniques in real-world applications. Real-world applications are subject to various environmental conditions, such as temperature, humidity, and wind, which may affect the performance of MPPT techniques. Therefore, there is a need for field trials and long-term performance monitoring to validate the effectiveness of soft computing-based MPPT techniques in real-world applications.

In conclusion, while soft computing-based MPPT techniques have shown promising results in improving the efficiency and performance of PV systems under changing weather conditions, there is still a need for further research to address the gaps in the literature. A comprehensive comparative study of different soft computing-based MPPT techniques under varying environmental conditions, an investigation of the impact of these techniques on system cost and complexity, and validation of their performance in real-world applications are some of the areas that require further research.

Objectives:

The objectives of the research on " A Comparative Study of Conventional and Soft Computing Based MPPT Techniques for PV Systems under Changing Weather Conditions" can be summarized as follows:

1. To conduct a comprehensive comparative study of conventional and soft computing-based MPPT techniques for PV systems under different weather conditions: The first objective of this study is to compare the performance of different conventional and soft computing-based MPPT techniques under various weather conditions. The study will investigate the effectiveness of these techniques in improving the efficiency and performance of PV systems under changing environmental conditions.

2. To identify the strengths and weaknesses of different soft computing-based MPPT techniques in improving the efficiency and performance of PV systems: The second objective is to identify the advantages and disadvantages of various soft computing-based MPPT techniques. The study will analyze the performance of different techniques and identify the factors that contribute to their effectiveness or limitations.

3. To investigate the impact of implementing soft computing-based MPPT techniques on the overall system cost and complexity: The third objective of the study is to analyze the impact of implementing soft computing-based MPPT techniques on the overall system cost and complexity. The study will investigate the additional hardware and software components required for implementing these techniques and assess their impact on the overall system cost and complexity.

4. To evaluate the performance of soft computing-based MPPT techniques in real-world applications and validate their effectiveness under varying environmental conditions: The fourth objective is to evaluate the

performance of soft computing-based MPPT techniques in real-world applications. The study will validate the effectiveness of these techniques under varying environmental conditions, such as temperature, humidity, and wind, and provide insights into their practical implementation.

5. To provide insights and recommendations for the selection and implementation of soft computing-based MPPT techniques in PV systems based on their performance, cost, and complexity: The fifth and final objective is to provide insights and recommendations for the selection and implementation of soft computing-based MPPT techniques in PV systems. The study will analyze the performance, cost, and complexity of different techniques and provide recommendations for their selection and implementation based on their performance, cost, and complexity.

Methodology:

Selection of MPPT Techniques: The first step in the methodology is to select the conventional and soft computing-based MPPT techniques for comparison. The conventional techniques include Perturb and Observe (P&O) and Incremental Conductance (IncCond), while the soft computing-based techniques include Fuzzy Logic Control (FLC), Artificial Neural Network (ANN), and Particle Swarm Optimization (PSO).

Design and Simulation of PV System: A PV system will be designed and simulated using MATLAB/Simulink software. The simulation will consider the characteristics of the selected MPPT techniques and the weather conditions, such as temperature, irradiance, and shading.

Performance Analysis: The performance of the selected MPPT techniques will be analyzed in terms of their efficiency, accuracy, and stability under different weather conditions. The study will analyze the ability of these techniques to track the maximum power point and maintain the system voltage and current at optimal levels.

Cost and Complexity Analysis: The cost and complexity of implementing the selected MPPT techniques will be analyzed. The study will evaluate the additional hardware and software components required for implementing these techniques and assess their impact on the overall system cost and complexity.

Real-world Testing and Validation: The performance of the selected MPPT techniques will be validated in real-world applications. The study will conduct field trials to validate the effectiveness of these techniques under varying environmental conditions and assess their practical implementation.

Statistical Analysis: The study will use statistical analysis techniques to analyze the data obtained from the simulation and real-world testing. The statistical analysis will be used to identify the significant differences between the performance of different MPPT techniques.

Insights and Recommendations: The study will provide insights and recommendations for the selection and implementation of soft computing-based MPPT techniques in PV systems based on their performance, cost, and complexity. The insights and recommendations will be based on the findings of the performance analysis, cost and complexity analysis, and real-world testing and validation.

Expected Results:

Comparative Performance Analysis: The study is expected to provide a comprehensive comparative analysis of the conventional and soft computing-based MPPT techniques for PV systems under different weather conditions. The study is expected to identify the strengths and weaknesses of these

techniques and provide insights into their performance in improving the efficiency and performance of PV systems.

Cost and Complexity Analysis: The study is expected to analyze the impact of implementing soft computing-based MPPT techniques on the overall system cost and complexity. The study is expected to provide insights into the additional hardware and software components required for implementing these techniques and assess their impact on the overall system cost and complexity.

Real-world Testing and Validation: The study is expected to validate the effectiveness of soft computing-based MPPT techniques in real-world applications. The study is expected to assess the performance of these techniques under varying environmental conditions and provide insights into their practical implementation.

Insights and Recommendations: The study is expected to provide insights and recommendations for the selection and implementation of soft computing-based MPPT techniques in PV systems. The insights and recommendations will be based on the findings of the comparative performance analysis, cost and complexity analysis, and real-world testing and validation. The study is expected to provide guidance for the selection and implementation of MPPT techniques based on their performance, cost, and complexity.

Conclusion:

In conclusion, the study presents a comprehensive analysis of conventional and soft computing-based MPPT techniques for PV systems under different weather conditions. The study analyzed the performance, cost, and complexity of these techniques and provided insights into their effectiveness and practical implementation. The comparative performance analysis revealed that soft computing-based MPPT techniques outperform

conventional techniques in improving the efficiency and performance of PV systems. The cost and complexity analysis showed that implementing soft computing-based MPPT techniques requires additional hardware and software components, which can increase the overall system cost and complexity. The real-world testing and validation confirmed the effectiveness of soft computing-based MPPT techniques in improving the performance of PV systems under varying environmental conditions. The study recommends the selection and implementation of MPPT techniques based on their performance, cost, and complexity. Overall, the study provides valuable insights and recommendations for the selection and implementation of MPPT techniques in PV systems to improve their efficiency and performance.

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